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Computer Program for Calculating Velocities and Streamlines on Mid-Channel Flow Surface of Axial or Mixed-Flow Turbomachine

A computer program has been developed which obtains a subsonic or transonic, nonviscous flow solution on the hub-shroud mid-channel flow surface of a turbomachine.

The design of blades for compressors and turbines ideally requires analysis methods for unsteady, rotational, three-dimensional, viscous flow through a turbomachine. Clearly, such solutions are impossible at the present time, even on the largest and fastest computers. The usual approach at present is to analyze only steady flows and to separate inviscid solutions from viscous solutions. At present, inviscid analyses usually involve a combination of several two-dimensional solutions on intersecting families of stream surfaces to obtain what is called a quasi-three-dimensional solution.

This computer program uses both a finite-difference and a stream filament (velocity gradient) method, combined in a way which takes maximum advantage of both. The finite-difference method is used to obtain a subsonic-flow solution. The velocity-gradient method is then used if necessary to extend the range of solutions into the transonic regime. The flow must be essentially subsonic, but there may be locally supersonic flow. The solution is for two-dimensional, adiabatic shock-free flow. The blade row may be fixed or rotating, and may be twisted and leaned. The flow may be axial or mixed, up to approximately 45° from axial. Upstream and downstream flow conditions can vary from hub to shroud, and provision is made for an approximate correction for loss of stagnation pressure.

The basic analysis is based on the stream function and consists of the solution of the simultaneous, non-linear, finite-difference equations of the stream function. This basic solution, however, is limited to strictly subsonic flow. When there is locally supersonic flow, a transonic solution must be obtained. The transonic solution is obtained by a combination of a finite-difference stream-function solution and a velocity-gradient solution. The finite-difference solution at a reduced mass flow provides information which is used to obtain a velocity-gradient solution at the full mass flow.

The program input consists of blade and flow-channel geometry, upstream and downstream flow conditions from hub to shroud, and mass flow. The output includes streamline coordinates, flow angles, and velocities on the mid-channel flow surface; incidence and deviation angles at the blade leading and trailing edges; and approximations to the blade surface velocities. The output may also include input information for a blade-to-blade flow analysis program.

Notes:

1. The program is reported in two volumes, with Part I as the User's Manual and Part II as the Programmer's Manual. Part I contains all the information necessary to use the program as is. It explains the equations involved and the method of solution and gives a numerical example to illustrate the use of the program. Part II includes the complete program listing and a detailed program procedure.
2. This program is written in FORTRAN IV for use on IBM TSS/360-67 equipment.
3. Inquiries concerning this program should be directed to:

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Category 09